ENVIRONMENT-FRIENDLY, RAPID METHODS FOR ORGANIC TRANSFORMATIONS USING NOVEL PALLADIUM NANOPARTICLES AS CATALYST

A
SYNOPSIS SUBMITTED
TO
MUMBAI UNIVERSITY, MUMBAI

FOR THE DEGREE
OF
DOCTOR OF PHILOSOPHY
IN
CHEMISTRY

UNDER THE FACULTY OF SCIENCE
BY

Mr. SUSHIL MOHAN BADADE
M.Sc. PET.

UNDER THE GUIDANCE OF
Dr. AMIT SHRIKANT VARALE
M.Sc., Ph.D.
DEPARTMENT OF CHEMISTRY

A.S.P. COLLEGE DEVRUKH

OCTOBER–2022

Scanned with OKEN Scanner

PROPOSAL FOR TOPIC APPROVAL TO BE SUBMITTED TO THE UNIVERSITY OF MUMBAI FOR THE Ph.D. DEGREE IN THE SUBJECT OF **CHEMISTRY.**

Title of the topic	:	"Environment-friendly rapid methods for organic transformations using novel palladium nanoparticles as catalyst"
Name of the Students	:	Mr. Sushil Mohan Badade
Basic Qualification	:	M.Sc. (Organic Chemistry), PET
In the case of Ph.D. student Year of Passing of PET/NET/SET/M.Phil. /GPAT /GATE (Teaching Experience)	:	PET 2022 10 Years, 9 Months (Industrial research and development experience)
Name of the Research Supervisor/Guide	:	Dr. Amit Shrikant Varale Assistant Professor in Chemistry
Date of Superannuation /Retirement of the Research Supervisor/Guide	:	30th November 2039.
Name of the Research Centre	:	A.S.P. College Devrukh, Dist.-Ratnagiri
Signature of the Student	:	Badade
Signature of the Research Supervisor/Guide	:	AVarale
Signature of the Head of Department	:	

PRINCIPAL.
NYA. ATHALYE ARTS VED. SAPRE COMMERCE
AND SMT. PITRE SCIENCE COLLEGE
DEVRUKH (DIST. RATNAGIRI) PIN - 415 804

Date: 08/10/2022 Signature of Head/Director/Dean of Research Centre

Seal of College/ Department

NYA. ATHALYE. VED. SAPRE. VID. PITRE COLLEGE • DEVRUKH

Scanned with OKEN Scanner

INDEX

Sr. No.	Content	Page Number
1	Title	1
2	Aims of the study	1
3	Objective of the study	1
4	Study Background (Literature Review) and significance of study	1
5	National Status	2
6	International Status	3
7	Study Hypotheses	4
8	Study Rationale	4
9	Research Methodology	5
10	Statistical Plan	5
11	Limitations of the Study	5
12	Expected Outcomes of Study	5
13	Select Bibliography	6

Scanned with OKEN Scanner

1. Title: "Environment-friendly rapid methods for organic transformations using novel palladium nanoparticles as catalyst"

2. Aim of Study

The aim of study is to synthesize palladium nanoparticles by using rapid, cost effective and environment-friendly synthesis. The aim of our study is to check its catalytic application in various organic transformations. Further, our study is to aimed to evaluate its various biological activities like antimicrobial, antioxidant activities etc....

3. Objective of the study

i) To develop environment-friendly synthesis for the palladium nanoparticles loaded on economical supports.

ii) To characterize the morphology and particle size of synthesized palladium nanoparticles.

iii) To develop advance methodologies and techniques for the synthesis of organic compounds by using palladium nanoparticles as a catalyst.

iv) Then the catalytic study of the synthesized palladium nanoparticles in various organic transformations.

v) Then study the recovered efficacy and reusability experiment of synthesized palladium nanoparticles.

vi) To evaluate the biological activities of synthesized palladium nanoparticle.

4. Study Background (Literature Review) and significance of study

Nowadays applicability of nanoparticles has a great attention in the field of medicines and catalysts [1]. Nanoparticles have a high surface to volume ratio with smaller size. A specific surface area of nanoparticles enhances the catalytic reactivity and other related biological activities such as antimicrobial activity [2] and antioxidant activity [3] etc. The metal nanoparticles and metal oxide nanoparticles were synthesized by using chemical [4, 5] and environment-friendly methods [6, 7]. Among this, there is a lot of review are available on a metal oxide nanoparticles (MONPs) such as Fe [8], Ru [9] and Ti [10].

Nowadays, due to applicability of the palladium nanoparticles in research, attracted considerable attention to researchers. The palladium nanoparticles have a remarkable catalytic application in coupling [11, 12], oxidation [13] and hydrodechlorination [14] due to excellent activity and high specificity. In this connection, due to high surface to volume ratio of synthesized palladium

Scanned with OKEN Scanner

nanoparticles they show remarkable catalytic activity in -C-C- bond formation in coupling reactions like Suzuki-Miyaura coupling reaction [15], Sonogashira coupling reaction [16] and Heck coupling reaction [17] etc. These reactions have a huge application in pharmaceutical [18], polymer, fine chemicals, dyes and pigment industries. The review on the reported palladium nanoparticle shows that the synthesis of PdNPs were carried out by using chemical reducing agent. The use of this PdNPs in organic transformation shows more time [19].

The palladium nanoparticles were synthesized by using chemical method. The reducing agents used are NaBH4 [20] and ethylene glycol [21] as a solvent. The chemical reducing agent used are harmful to environment. To overcome this, the palladium nanoparticles are synthesized by using environment-friendly synthesis. In this connection, the plant part like leaf, flower and bark extract is used as reducing and stabilizing agent for the synthesis of palladium nanoparticles [22]. The heterogeneous palladium nanoparticles are prepared by using various economical supports like Bentonite clay [23] and Zeolite-Y (Na form) [24]. These heterogeneous palladium nanoparticles are easy to separate from reaction mass as compared with homogenous palladium nanoparticles.

In this work we are focusing to synthesize palladium nanoparticle on various economical supports which helps to separate reactions mass from the catalyst. We are focusing on the easily available local materials as supports for loading palladium nanoparticles.

5. National Status

The palladium nanoparticles have many applications in various fields like medicine and catalysts in organic transformations [11-14].

Saikia et al. reported a green synthesis of palladium nanoparticles supported on modified montmorillonite by using aqueous *Ocimum sanctum* leaf extract [14]. The catalytic activity of this supported palladium nanoparticles was checked for hydrodechlorination of 4-chlorophenol. This catalyst was recovered by simple filtration and recycled for several run without any significant loss of efficacy. Manjare and Chaudhari synthesized palladium nanoparticles loaded on Zeolite Type-Y (Na-form) using *Anacardium occidentale* shell extract (Cashew nut shell extract) [24]. The catalytic activity of this catalyst was examined for Suzuki-Miyaura coupling reaction. This catalyst shows remarkable percentage yield for biphenyl products. The process of recycling of catalyst was repeated up to ten times without significant loss of catalytic activity. There is scope to use the present strategy in various organic transformation. Manjare et al.

Scanned with OKEN Scanner

reported the biosynthesis of palladium nanoparticles from *Moringa oleifera* leaf extract supported on activated Bentonite clay [25]. The *Moringa oleifera* leaf extract acts as a reducing and capping agent. The palladium nanoparticles loaded on activated Bentonite clay acts as good catalyst in Suzuki-Miyaura coupling reaction and oxidation reaction. This catalyst shows remarkable recyclability result up to five times in coupling and oxidation reaction. Manjare and Chaudhari designed a palladium nanoparticle-Bentonite hybrid using *Syzygium aqueum* leaves extract [23]. The catalytic activity was assessed in -C-C- coupling reaction. It was found that catalyst shows good catalytic activity in Suzuki-Miyaura reaction. This catalyst shows good recyclability result up to ten times. This catalyst was found to be stable after recyclability test. Manjare et al. reported a resin loaded palladium nanoparticle and its application in Suzuki Miyaura coupling reaction [26]. In this work, the palladium nanoparticles were prepared by using chemical reducing and capping agent like NaBH4 and organic solvent MeOH:Dioxane (2:1). The catalytic activity of synthesized PdNPs loaded on Dianion^{TM}PK228 were assessed against Suzuki-Miyaura coupling reaction. The recyclability result of synthesizes PdNPs loaded on resin shows good results up to ten times. Manjare et al. in 2021 have taken review on the synthesis of PdNPs using plant part extract [11]. The highlight of the study was the synthesis of PdNPs and their catalytic applications. However, there is scope to discuss the bioreduction mechanism of formation of PdNPs.

6. International Status

The palladium nanoparticles were prepared by using chemical method [26] and environment-friendly method [11].

Nguyen et al. reported a chemical synthesis method of palladium nanoparticles [27]. Various size and shape of PVP-PdNPs were synthesized by using ethylene glycol as a chemical reducing agent. Wei et al. synthesized palladium nanoparticles by using chemical method [28]. This catalytic activity of synthesized palladium nanoparticles was checked in Suzuki-Miyaura coupling reaction. These size controlled PdNPs was synthesized by using amyloid fibrils as a bio-templates. The Pd-insulin fibril was prepared by using layer-by-layer technology. The Pd-insulin fibril shows high isolated product in Suzuki-Miyaura reaction. Baran et al. reported the synthesis of new chitosan supported Pd catalyst [29]. The catalytic activity of synthesized chitosan supported Pd catalyst was assessed against Suzuki coupling reaction and H2O2 decomposition reaction. The redox potential of synthesized Pd catalyst was high with negligible

Scanned with OKEN Scanner

weight loss after ten cycles in reusability tests. Khan et al. synthesized miswak mediated palladium nanoparticles as an effective catalyst in Suzuki coupling reaction in aqueous media [30]. This PdNPs exhibit a superior catalytic activity and reusability in Suzuki-Miyaura coupling reaction in aqueous media. The kinetics of reaction was studied by using GC. GC study reveals that conversion of aryl halide and aryl boronic acid in short time. Shaik et al. reported a green synthesis of palladium nanoparticles using *Origanum vulgare* leaf extract [31]. The catalytic activity was checked in oxidation reaction of alcohol. Baran et al. reported the synthesis of Pd(0) nano catalyst stabilized novel agar/pectin composite [32]. This shows remarkable catalytic activity in Suzuki-Miyaura cross coupling reaction and reduction of o-nitroaniline to 1,2-benzenediamine at room temperature in water. This catalyst shows good catalytic and reusability results. Tadjarodi et al. reported effective, simple and environmental beneficial ultrasound method for the synthesis of palladium nanoparticles supported on Zeolite–Y [33]. This synthesized catalyst has a more advantages in Suzuki-Miyaura coupling reaction. The results of this catalyst in Suzuki-Miyaura reaction shows short reaction time, high yield of biphenyl derivative and good recyclability result. There is scope to develop environment-friendly method for synthesis of palladium nanoparticles. The catalytic activity can be further checked for other organic transformations.

7. Study Hypothesis

The heterogeneous palladium nanoparticles are good to separate from reaction mass. The assessment of catalytic activity of heterogeneous palladium nanoparticles may have acceptable result. The heterogeneous palladium nanoparticles may be characterized by using HR-TEM and XRD for determination morphology and structure. The products formed after organic transformation is characterized by using FTIR, ^{1}H, ^{13}C and GC-MS. Newer techniques have been established to form organic products by adopting various recent advanced methods in presence of PdNPs as a catalyst.

8. Study Rationale

The synthesized heterogeneous palladium nanoparticles may show remarkable result in organic transformations. This may give a good alternative for other reported catalyst for various organic transformations. The biological activity of heterogonous pallidum nanoparticles may show acceptable zone of inhibition.

Scanned with OKEN Scanner

9. Research Methodology

To from new C-C bond aryl halides, boronic acids, inorganic and organic bases, phase transfer catalyst tetra-butyl ammonium bromide, solvents, TLC plates, silica gel will be procured from vendors. Appropriate millimoles of reactant, catalyst and suitable solvent will be used to from new C-C bond, whenever column purification is required, it will be done by column chromatography using silica gel as stationary phase and mixture of organic solvents as mobile phase. Catalyst used for the reactions will be recovered and recycled. Above pure compounds will be characterized by NMR, Mass and FTIR. These methods will be used for optimization of C-C coupling reaction which are used in API in pharmaceutical.

10. Statistical Plan

Months	Plan of Research work
1 to 6	Course work and Literature review
7 to 20	Laboratory work
21 to 30	Result analysis and outcome
31 to 36	Synopsis and thesis writing

11. Limitation of the Study

The palladium salts have a various type of ligand. These palladium salts are toxic which deviates from 12 principles of green chemistry. We are focusing the loading of small amount of palladium nanoparticles on various economical supports. This PdNPs synthesis may use in organic transformation in industrial scale.

12. Expected Outcome of Study

- The synthesized heterogeneous palladium nanoparticles may be the best alternative to other reported palladium nanoparticle catalyst.
- The environment-friendly synthesis of heterogeneous PdNPs will give particle size in the range of 1 nm to 100 nm.
- The expected morphology of the synthesized PdNPs may have a good catalytic activity in various organic transformations. Which may have a useful application in pharmaceutical, polymer, fine chemical and dyes and pigment industry.
- The biological activity of synthesized PdNPs and the compound synthesized using PdNPs may have a remarkable result.

Scanned with OKEN Scanner

13. Select Bibliography

[1] D. Yohan and B. D. Chithrani, "Applications of nanoparticles in nanomedicine," *J. Biomed. Nanotechnol.*, vol. 10, no. 9, pp. 2371–2392, 2014, doi: 10.1166/jbn.2014.2015.

[2] S. B. Manjare, P. P. Paranjape, V. L. Gurav, P. P. Shinde, R. R. Chavan, and S. R. Thopate, "Silver nanoparticles synthesis using AH leaf extract and its antimicrobial activity," *Bioinspired, Biomim. Nanobiomaterials*, vol. 9, no. 3, pp. 190–193, 2020, doi: 10.1680/jbibn.19.00047.

[3] J. A. A. Abdullah, L. Salah Eddine, B. Abderrhmane, M. Alonso-González, A. Guerrero, and A. Romero, "Green synthesis and characterization of iron oxide nanoparticles by pheonix dactylifera leaf extract and evaluation of their antioxidant activity," *Sustain. Chem. Pharm.*, vol. 17, no. April, 2020, doi: 10.1016/j.scp.2020.100280.

[4] L. T. A. Nhien, N. D. Luong, L. T. T. Tien, and L. Q. Luan, "Radiation Synthesis of Silver Nanoparticles/Chitosan for Controlling Leaf Fall Disease on Rubber Trees Causing by Corynespora cassiicola," *J. Nanomater.*, vol. 2018, 2018, doi: 10.1155/2018/7121549.

[5] G. M. Scheuermann, L. Rumi, P. Steurer, W. Bannwarth, and R. Mu, "Palladium Nanoparticles on Graphite Oxide and Its Functionalized Graphene Derivatives as Highly Active Catalysts for Suzuki-Miyaura Coupling Reaction," *J. Am. Chem. Soc.*, vol. 131, pp. 8262–8270, 2009.

[6] S. O. Aisida, K. Ugwu, A.C. Nwanya, A. K. H. Bashir, N. U. Nwankwo, I. Ahmad, and F.I. I. Ezema, "Biosynthesis of silver oxide nanoparticles using leave extract of Telfairia Occidentalis and its antibacterial activity," *Mater. Today Proc.*, vol. 36, pp. 208–213, 2019, doi: 10.1016/j.matpr.2020.03.005.

[7] S. B. Manjare, S. G. Sharma, V. L. Gurav, M. R. Kunde, and S. S. Patil, "Biosynthesis of silver nanoparticles using leaf and bark extract of indian plant carissa carandas, characterization and antimicrobial activity," *Asian J. Nanosci. Mater.*, vol. 3, pp. 58–66, 2020, doi: 10.26655/AJNANOMAT.2020.1.6.

[8] N. Madubuonu, S. O. Aisida, A. Ali, I. Ahmad, T. Zhao, S. Botha, M. Maaza, F. I. Ezema, "Biosynthesis of iron oxide nanoparticles via a composite of Psidium guavaja-Moringa oleifera and their antibacterial and photocatalytic study," *J. Photochem. Photobiol. B Biol.*, vol. 199, no. June, p. 111601, 2019, doi: 10.1016/j.jphotobiol.2019.111601.

[9] S. M. Anjum and K. Riazunnisa, "Fine Ultra-small Ruthenium Oxide Nanoparticle

Scanned with OKEN Scanner

Synthesis by Using Catharanthus roseus and Moringa oleifera Leaf Extracts and Their Efficacy Towards in Vitro Assays, Antimicrobial Activity and Catalytic: Adsorption Kinetic Studies Using Methylene Blue Dye," *J. Clust. Sci.*, vol. 33, no. 3, pp. 1103–1117, 2022, doi: 10.1007/s10876-021-02037-0.

[10] M. S. Waghmode, A. B. Gunjal, J. A. Mulla, N. N. Patil, and N. N. Nawani, "Studies on the titanium dioxide nanoparticles: biosynthesis, applications and remediation," *SN Appl. Sci.*, vol. 1, no. 4, pp. 1–9, 2019, doi: 10.1007/s42452-019-0337-3.

[11] S. B. Manjare, P. D. Pendhari, S. M. Badade, and S. R. Thopate, "Palladium Nanoparticles: Plant Aided Biosynthesis, Characterization, Applications," *Chem. Africa*, vol. 4, no. 4, pp. 715–730, 2021, doi: 10.1007/s42250-021-00284-2.

[12] M. Nasrollahzadeh, S. M. Sajadi, E. Honarmand, and M. Maham, "Preparation of palladium nanoparticles using Euphorbia thymifolia L. leaf extract and evaluation of catalytic activity in the ligand-free Stille and Hiyama cross-coupling reactions in water," *New J. Chem.*, vol. 39, no. 6, pp. 4745–4752, 2015, doi: 10.1039/c5nj00244c.

[13] N. Gogoi, P. Bordoloi, G. Borah, and P. K. Gogoi, "Synthesis of Palladium Nanoparticle by Bio-reduction Method and Its Effectiveness as Heterogeneous Catalyst Towards Selective Oxidation of Benzyl Alcohols in Aqueous Media," *Catal. Letters*, vol. 147, no. 2, pp. 539–546, 2017, doi: 10.1007/s10562-016-1937-9.

[14] P. K. Saikia, R. P. Bhattacharjee, P. P. Sarmah, L. Saikia, and D. K. Dutta, "A green synthesis of Pd nanoparticles supported on modified montmorillonite using aqueous: Ocimum sanctum leaf extract: A sustainable catalyst for hydrodechlorination of 4-chlorophenol," *RSC Adv.*, vol. 6, no. 111, pp. 110011–110018, 2016, doi: 10.1039/c6ra22788k.

[15] R. Lakshmipathy, B. Palakshi Reddy, N. C. Sarada, K. Chidambaram, and S. Khadeer Pasha, "Watermelon rind-mediated green synthesis of noble palladium nanoparticles: catalytic application," *Appl. Nanosci.*, vol. 5, no. 2, pp. 223–228, 2015, doi: 10.1007/s13204-014-0309-2.

[16] A. Dewan, M. Sarmah, A. J. Thakur, P. Bharali, and U. Bora, "Greener Biogenic Approach for the Synthesis of Palladium Nanoparticles Using Papaya Peel: An Eco-Friendly Catalyst for C-C Coupling Reaction," *ACS Omega*, vol. 3, no. 5, pp. 5327–5335, 2018, doi: 10.1021/acsomega.8b00039.

[17] C. Garai, S. N. Hasan, A. C. Barai, S. Ghorai, S. K. Panja, and B. G. Bag, "Green

Scanned with OKEN Scanner

synthesis of Terminalia arjuna-conjugated palladium nanoparticles (TA-PdNPs) and its catalytic applications," *J. Nanostructure Chem.*, vol. 8, no. 4, pp. 465–472, 2018, doi: 10.1007/s40097-018-0288-z.

[18] S. S. Rokade, K.A. Joshi, K. Mahajan, S. Patil, G. Tomar, D. S. Dubal, V. S. Parihar, R. Kitture, J. R. Bellare, and S. Ghosh, "Gloriosa superba Mediated Synthesis of Platinum and Palladium Nanoparticles for Induction of Apoptosis in Breast Cancer," *Bioinorg. Chem. Appl.*, vol. 2018, 2018, doi: 10.1155/2018/4924186.

[19] M. Khan, G. H. Albalawi, M.R. Shaik, M. Khan, S. F. Adil, M. Kuniyil, H. Z. Alkhathlan, A. Al-Warthan, and M. R. H. Siddiqui, "Miswak mediated green synthesized palladium nanoparticles as effective catalysts for the Suzuki coupling reactions in aqueous media," *J. Saudi Chem. Soc.*, 2016, doi: 10.1016/j.jscs.2016.03.008.

[20] K. A. De Castro and H. Rhee, "Resin-immobilized palladium nanoparticle catalysts for Suzuki-Miyaura cross-coupling reaction in aqueous media," *J. Incl. Phenom. Macrocycl. Chem.*, vol. 82, no. 1, pp. 13–24, 2015, doi: 10.1007/s10847-014-0428-0.

[21] K. Lamei, H. Eshghi, M. Bakavoli, and S. Rostamnia, "Highly dispersed copper/ppm palladium nanoparticles as novel magnetically recoverable catalyst for Suzuki reaction under aqueous conditions at room temperature," *Appl. Organomet. Chem.*, vol. 31, no. 11, pp. 1–13, 2017, doi: 10.1002/aoc.3743.

[22] F. Qazi, Z. Hussain, and M. N. Tahir, "Advances in biogenic synthesis of palladium nanoparticles," *RSC Adv.*, vol. 6, no. 65, pp. 60277–60286, 2016, doi: 10.1039/c6ra11695g.

[23] S. B. Manjare and R. A. Chaudhari, "Palladium Nanoparticle-Bentonite Hybrid Using Leaves of Syzygium aqueum Plant from India: Design and Assessment in the Catalysis of –C–C– Coupling Reaction," *Chem. Africa*, vol. 3, no. 2, pp. 329–341, 2020, doi: 10.1007/s42250-020-00139-2.

[24] S. B. Manjare and R. A. Chaudhari, "Environment-friendly synthesis of palladium nanoparticles loaded on Zeolite Type-Y (Na-form) using Anacardium Occidentale shell extract (Cashew nut shell extract), characterization and application in -C-C- coupling reaction," *J. Environ. Chem. Eng.*, vol. 8, no. 5, p. 104213, 2020, doi: 10.1016/j.jece.2020.104213.

[25] S. B. Manjare, P. D. Pendhari, S. M. Badade, S. R. Thopate, and M. S. Thopate, "Biosynthesis of Palladium Nanoparticles from Moringa oleifera Leaf Extract Supported

Scanned with OKEN Scanner

on Activated Bentonite Clay and Its Efficacy Towards Suzuki – Miyaura Coupling and Oxidation Reaction," *Bionanoscience*, vol. 12, pp. 785-794, 2022, doi: 10.1007/s12668-022-01011-y.

[26] S. B. Manjare, R. A. Chaudhari, S. R. Thopate, K. P. Risbud, and S. M. Badade, "Resin loaded palladium nanoparticle catalyst, characterization and application in –C–C– coupling reaction," *SN Appl. Sci.*, vol. 2, no. 5, pp. 1–6, 2020, doi: 10.1007/s42452-020-2795-z.

[27] N. V. Long, D. C. Nguyen, H. Hirata, M. Ohtaki, T. Hayakawa, and M. Nogami, "Chemical synthesis and characterization of palladium nanoparticles," *Adv. Nat. Sci. Nanosci. Nanotechnol.*, vol. 1, no. 3, 2010, doi: 10.1088/2043-6262/1/3/035012.

[28] Y. H. Wei, L. J. Wang, X. H. Zhao, C. C. Li, L. X. Kong, and X. F. Zhou, "Palladium Nanoparticles Synthesized by Bio-Templates for Suzuki Coupling Reaction," *Adv. Mater. Res.*, vol. 1118, pp. 14–19, 2015, doi: 10.4028/www.scientific.net/amr.1118.14.

[29] T. Baran, T. Inanan, and A. Menteş, Synthesis, characterization, and catalytic activity in Suzuki coupling and catalase-like reactions of new chitosan supported Pd catalyst, *Carbohydrate Polymers,* vol. 145. pp. 20-29, 2016. Doi: 10.1016/j.carbpol.2016.03.019.

[30] M. Khan, G. H. Albalawi, M. R. Shaik, M. Khan, S. F. Adil, M. Kuniyil, H. Z. Alkhathlan, A. Al-Warthan, and M. R. H. Siddiqui, "Miswak mediated green synthesized palladium nanoparticles as effective catalysts for the Suzuki coupling reactions in aqueous media," *J. Saudi Chem. Soc.*, vol. 21, no. 4, pp. 450–457, 2017, doi: 10.1016/j.jscs.2016.03.008.

[31] M. Rafi Shaik, Z. J. Q. Ali, M. Khan, M. Kuniyil, M. E. Assal, H. Z. Alkhathlan, A. Al-Warthan, M. R. H. Siddiqui, M. Khan, and S. F. Adil, "Green synthesis and characterization of palladium nanoparticles using origanum vulgare L. extract and their catalytic activity," *Molecules*, vol. 22, no. 1, 2017, doi: 10.3390/molecules22010165.

[32] T. Baran, "Pd(0) nanocatalyst stabilized on a novel agar/pectin composite and its catalytic activity in the synthesis of biphenyl compounds by Suzuki-Miyaura cross coupling reaction and reduction of o-nitroaniline," *Carbohydr. Polym.*, vol. 195, no. April, pp. 45–52, 2018, doi: 10.1016/j.carbpol.2018.04.064.

[33] A. Tadjarodi, M. Dehghani, and M. Imani, "Green synthesis and characterization of palladium nanoparticles supported on zeolite Y by sonochemical method, powerful and

Scanned with OKEN Scanner

efficient catalyst for Suzuki-Miyaura coupling of aryl halides with phenylboronic acid," *Appl. Organomet. Chem.*, vol. 32, no. 12, pp. 1–10, 2018, doi: 10.1002/aoc.4594.

Badade

Mr. Sushil Mohan Badade

(Research student)

Dr. Amit Shrikant Varale

(Research Guide)

Scanned with OKEN Scanner